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ABSTRACT

The purpose of this study was to verify that mean cloze scores predict the reading difficulty of passages written in mathematical English. Twenty-two mathematical passages exemplifying different writing styles and content were selected from instructional materials written for upper elementary school and junior and senior high school. Using a fifth word or symbol deletion pattern, two cloze forms were constructed for each passage, and one multiple-choice reading test developed for each passage. Subjects from grades seven through ten in fourteen schools were randomly assigned to groups as defined by the forty-four different cloze forms, two for each passage. Each subject responded to cloze tests on one day, and a week later the subject read the complete passage and took a comprehension test on the passage. The results of the study indicated that the reading comprehension tests are reliable measures and can be used as criterion measures to test the validity of cloze tests for the difficulty of mathematical English. The reliabilities of all cloze tests are very high. Cloze tests can be used as predictors of reading difficulty for mathematical English content. (Author/WR)

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The Cloze Procedure as a Measure of the Reading Difficulty of Mathematical English Passages

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Summary

The purpose of this study is to verify that mean cloze scores predict the reading difficulty of passages written in mathematical English. A cloze test is constructed by replacing every nth word or symbol in a passage with a blank. The subject is to fill in the blanks. His score is the number of correct insertions.

Twenty-two mathematical passages exemplifying different writing styles and content were selected from instructional materials written for upper elementary school and junior and senior high school. Using a fifth word or symbol deletion pattern, two cloze forms were constructed for each passage. One multiple-choice reading test for each passage was developed by the efforts of professional mathematicians, classroom teachers, and trained test constructors. In the construction of comprehension tests, special attention was given to the proper sampling of content from passages, to the level at which questions were written, and to language format.

Subjects from grades seven through ten in fourteen schools were randomly assigned to groups as defined by the forty-four different cloze forms, two for each passage. Each subject responded to a cloze test on one day. A week later the subject read the passage for which the cloze test was constructed and took a comprehension test on the passage. The K-R internal consistency formula 20 was used to calculate the reliabilities of cloze and comprehension tests.

The results of the study indicate that the reading comprehension tests are reliable measures and can be used as criterion measures to test the validity of cloze tests for the difficulty of mathematical English. The reliabilities of all cloze tests are very high. One factor which accounts for the high reliabilities is the length of the tests. The strong relationship between results on comprehension tests and cloze tests indicates that cloze tests are valid predictors of reading difficulty for mathematical English. Results are verified across grades and for grades seven through ten. There seems to be little evidence that it is better

to use two cloze forms for a passage than one in predicting the reading difficulty of a passage. Although subjects in higher grades in school obtain better scores for reading difficulty than those in lower grades, students in different grades rank passages according to difficulty in nearly the same way. In general, the results suggest that cloze tests can be used as predictors of reading difficulty for mathematical English content.

Introduction

This research is one step toward the realization of a readability formula for the prediction of difficulty of mathematical English. Efforts to use traditional readability formula validated for ordinary English prose are inappropriate because of the fundamental differences between ordinary English and mathematical English.

One of the problems faced by researchers attempting to develop formulas for the prediction of reading difficulty is the construction of valid criterion measures. In this study, the cloze technique is applied to mathematical English and validated as a measure of reading difficulty of instructional materials written in mathematical English. This validation will enable researchers to substitute cloze test scores for traditional reading comprehension test scores as criterion variables in developing a prediction equation of the reading difficulty of passages written in mathematical English. This achievement will permit the validation of potential predictor variables for mathematical English.

Comprehension test scores were used as criterion measures in many traditional readability formulas for ordinary English. But comprehension tests exhibit several deficiencies which reduce their efficiency and validity as criterion measures for mathematical English:

(1) A comprehension test may measure the readability of the test and not of the passage. When scores from criterion measures over different passages are compared, one

passage may be ranked more difficult than another simply because its comprehension test was more difficult to read.

(2) Test items on a comprehension test may not have the same degree of difficulty as the content of the passage. The difficulty of a passage can be altered by changing the test questions on the comprehension test over the passage.

(3) Comprehension tests usually cannot measure reliably small units of language, such as words and phrases. It seems likely that measures of words, phrases, and sentences will evaluate some potential predictor variables more successfully than larger units.

(4) There is no body of comprehension tests available for mathematics as there is for English. The construction of 50 to 100 reliable and valid comprehension tests is a monumental task.

A cloze test is formed by replacing every nth word in a passage with a blank. The subject is to fill in the blanks. His score is the number of correct insertions. Generally every fifth word is deleted, but other deletion patterns may be employed. The cloze procedure offers a palatable alternative to using comprehension tests as criterion measures for three reasons:

(1) The language of cloze tests is the same as that of the passages. It appears that more of the syntactic and semantic structures of the passage are retained in cloze tests than in comprehension tests.

(2) It is possible to obtain a measure for every word, phrase, sentence, paragraph, and passage by using alternate cloze test forms over a given passage.

(3) The simplicity of construction of cloze tests make it desirable to substitute cloze

tests for comprehension tests as criterion measures.

The cloze technique has been adapted to be used with mathematical English (Kane and Hater, 1968; Hater, 1969; Hater and Kane, 1970). This adaption involved the definition of units for deletion and the ordering of units. The basic units of deletion are tokens. Working definitions of token were developed and used empirically. The following definitions were subsequently employed:

(1) A word-token was defined as a unit of alphabetical signs having lexical meaning and separated from surrounding context by spaces (e.g., circle, the, following).

(2) A math-token was defined as a symbol unique to mathematics which does not have a phoneme-grapheme relationship with spoken words (e.g., 3, $, <, +).

To construct cloze tests, an ordering of tokens of deletion is needed. In ordinary English, there is a linear ordering of tokens on a page. In mathematics a two-dimensional arrangement exists. In the language of mathematics, the ordering imposed by vocalization is the ordering used to construct cloze tests. (e.g., $4 + \frac{1}{3}$ is ordered 4, +, 1, --, 3). The translation is not unique from the vocalization to the tokens on the page. For the sake of this study it is sufficient that the same translation be used as different cloze tests are constructed for the same passage. (e.g., 2^3 can be ordered 2, 3 or 3, 2 as determined by two-squared or the square of two.) Several lines from a cloze test are given in Figure 1. A sample of a passage with two cloze tests is given in Appendix C.

A study of Figure 1 reveals that a variety of techniques are used to respond to cloze test items. These include recognition of structure words, use of contextual clues, former knowledge, and guessing.

To validate adapted cloze tests as measures of difficulty for mathematical English, comprehension tests were used. Unlike ordinary English, there is no body of comprehension tests available for

mathematics. Therefore, the initial task in this research was the construction of comprehension tests for mathematical passages. Efforts were made to control the deficiencies present when comprehension tests are used as criterion measures of difficulty.

A rational number _____ any number which can _____ expressed as the ratio _____ an integer and a _____number.
75% _____ a rational number. Why?
_____ of the following represent _____ numbers?

$\frac{6}{7}$, ___42, +6, $\frac{\quad}{4}$

A rational number is any number which can be expressed as the ratio of an integer and a counting number.
75% is a rational number. Why?
Which of the following represent rational numbers?

$\frac{6}{7}$, 142, +6, $\frac{1}{4}$

Figure 1. Sample from a Cloze Test.

Review of Related Literature

This study was concerned with the construction of comprehension tests to be used to validate cloze tests as measures of difficulty for mathematical English. The research reviewed consists of studies concerned with (1) cloze tests for ordinary English, (2) comprehension tests as criterion of difficulty, and (3) cloze tests for mathematical English.

Cloze Tests for Ordinary English

The following review suggests that cloze scores are reliable and valid criterion measures in ordinary English and that they appear to behave in a like manner in mathematical English. Verification of this hypotheses is sought in this study.

Cloze tests have been used to measure constructs in both written and oral communication in English

(Taylor, 1953, 1954, 1957; Bormuth, 1962, 1963,1966; Fletcher, 1959; Jenkinson, 1957; Rankin, 1957; Friedman, 1964; Gallant, 1965). These studies indicate that cloze tests are reliable and valid measures of reading comprehensibility and difficulty for ordinary English passages.

In validating the cloze technique as a measure of difficulty for ordinary English, Taylor (1953) used as the criterion measure the grade placement of passages as defined by existing readability formulas. In developing the most recent formulas of readability, passages were often ranked by using grade scores from other readability formulas as the criterion measures. However, the application of these formulas to mathematical English is not justified unless they are adapted to be used with mathematical English (Kane, 1967-8; Kane, 1970).

Comprehension Tests as Criterion of Difficulty

In the literature which describes the construction of formulas for assessing the readability of ordinary English, three criteria of the difficulty of the passages were: (1) tests of comprehension, (2) judgment, and (3) the average reading ability of the subjects who enjoy the book or passage (Chall, 1958, p. 16).

The most frequently used criterion measures of difficulty in the past have been comprehension tests. The McCall-Crabbs Standard Tests in Reading (McCall & Crabbs, 1925) were the most frequently used tests in studies which employed comprehension tests as criterion measures. After revision of the tests in 1950, many of the well-known formulas were recalculated. The literature reveals that comprehension tests are acceptable as criterion measures of difficulty for ordinary English. However, as has been pointed out by Lorge (cited by Chall) and Chall (1958, p. 40), there are problems in using comprehension tests as criterion measures.

> If the questions are couched in a vocabulary less common than that used in the passages, fewer of them will be answered correctly; or if the questions require inferences that only well-informed or mature persons could make, few will be answered correctly (Lorge, 1949, p. 89).

However, until the cloze tests were validated as criterion measures of difficulty for ordinary English, there was no instrument generally accepted to be better than comprehension tests.

Cloze Tests for Mathematical English

Standard tests in reading ordinary English are available for validation purposes. But, no body of comprehension tests exists for the validation of mathematical English. What about the use of cloze tests to measure reading comprehensibility and difficulty in special hybrid languages such as technical scientific writing or mathematical English? Kane (1967,1970) has pointed out differences in redundancy characteristics, denotative theory, descriptive word usages and grammatical and syntactical flexibility between ordinary English and mathematical English. These differences cast serious doubt on the validity of applying traditional measures of reading comprehensibility and difficulty to mathematical English material. Is it feasible to use the cloze procedure in mathematical English?

The authors of this proposal have undertaken to adapt the cloze procedure for use with mathematical English (Kane and Hater, 1968; Hater, 1969; Hater and Kane, 1970). Several major generalizations related to resolving the salient problems of adaptation have emerged from these studies:

(1) Five alternative cloze tests were constructed over a number of passages. The first form was generated by beginning the every fifth-token deletion system with token number one. The second form was generated by beginning with token number two. The remaining forms were generated by beginning the deletion pattern with tokens three, four, and five respectively. No evidence indicated that different means or variances over cloze scores result across the alternative forms.

(2) It was hypothesized that responding to a cloze test prior to reading a passage and taking a traditional reading comprehension test might effect subjects' performances on the comprehension test. The evidence indicated that this fear was not justified.

(3) Kuder-Richardson formula 20 reliability coefficients for cloze tests each containing approximately 130 blanks ranged from 0.91 to 0.97. Since cloze items are certainly not of equal difficulty, these coefficients tend to underestimate within-test reliability. Reliabilities of responses from samples of 200 subjects differed very little from those based on samples of 30 subjects.

(4) A linear regression model should be used to characterize the relationship between cloze scores and reading comprehension scores over passages written in mathematical English.

(5) A product-moment correlation coefficient of 0.69 appears to be an estimate of the relationship between cloze scores and reading comprehension scores over a simple passage. (Since cloze test reliabilities ranged from 0.91-0.97 and comprehension test reliabilities ranged from 0.78-0.92, a correlation of 0.69 accounts for a large part of the variance.)

(6) For a given mathematical English passage the cloze score of a subject may be used to predict his reading comprehension test score over the same passage.

(7) To measure reading difficulty a comparison was made between means of cloze and comprehension tests over different passages. The product-moment correlation between mean cloze tests scores and mean comprehension test scores for five passages written in mathematical English was 0.83. Only one inversion was found in the ranking. While this is an optimistic finding the small number of passages suggests extreme caution in its interpretation. For example, for three degrees of freedom, 0.83 is not significantly different from 0.00 at the $\alpha = 0.05$ level.

These findings lay the groundwork for using the cloze procedure to assess the reading difficulty of instructional materials written in mathematical English without resorting to cumbersome experimental designs.

It was concluded from the studies that adapted

cloze tests for mathematical English passages are reliable and valid predictors of reading comprehensibility.

In summary, the cloze technique has been validated as a measure of reading comprehensibility and difficulty for ordinary English. Until the cloze tests were validated, the most common criterion measure of difficulty was the comprehension tests. The application of readability formulas to mathematical English is not valid if the formula is obtained from results using criterion measure and variables of the ordinary English language.

The cloze technique has been adapted to be used for mathematical English. Using comprehension tests as criterion measures, the cloze technique has been found to be a valid predictor of reading comprehensibility for instructional materials written in mathematical English.

Objectives of Investigation

The work accomplished to date offers strong encouragement to extend the correlation and regression analyses of mean cloze scores-mean reading comprehension scores to measure reading difficulty of passages written in mathematical English using mean cloze scores. Once done this will make it possible for researchers to validate potential predictor variables such as vocabulary familiarity, mean sentence length, et cetra against cloze score data. Since highly reliable cloze tests may be generated algorithmically from passages, data from sufficiently large numbers of passages may be obtained. Construction of traditional reading comprehension tests on a large number of passages written in mathematical English would be a formidable task.

At this juncture, definitional, psychometric, and experimental design problems which relate to the use of cloze tests with material written in mathematical English have been resolved and cloze scores have been shown to predict a subject's performance on a reading comprehension test.

Consequently, the main objective in this research is:

(1) To verify that mean cloze scores predict the reading difficulty of passages written in mathematical English.

To accomplish this objective, a series of multiple choice tests were constructed to be used as criterion measures of difficulty. Due to the problems inherent in comprehension tests, the tests were developed by the efforts of mathematicians, teachers, and test constructors who attempted to resolve problems of sampling of content, depth of writing and language. Thus, a secondary objective was:

(2) To construct comprehension tests which could be used as valid criterion measures of difficulty for mathematical English.

Development of Materials and Procedures

The main objective in the present study is the validation of cloze tests as criterion measures of difficulty for mathematical English. In order to accomplish this objective, passages were selected for study, comprehension tests were developed for the passages, and two cloze forms were constructed for each passage. Finally, appropriate experimental procedures for testing were determined and initiated.

Selection and Development of Passages

Twenty-two mathematical passages of approximately 600 tokens each were selected from textbooks, Grades 6 to 11 and from enrichment materials. About two-thirds of the materials came from textbooks and one-third from enrichment materials. Passages were distributed evenly across grades and included materials on numbers and arithmetic operations, non-metric, metric, and coordinate geometry, algebra, and assorted topics such as matrices, topology, and logic. Table 5 in Appendix A gives a listing of titles of passages.

In some instances, passages were altered from their original form in order to be used more effectively in the study. Thus, some passages are referred to as text passages (the passage as found in the textbook) and experimental passages (the passages as altered for this study). Questions included in a passage were

ordinarily retained so as not to change the style of the passage, but long exercises were eliminated or shortened. In some instances, this caused a variation in the amount of math-tokens in the text passage and the experimental passage. Therefore, the indices of difficulty obtained in the experimental results are for the experimental passages. Pictures and graphs from the text passages were included in the experimental passages. Passages were selected to allow for a variety of styles. Nineteen different author teams were included in the sampling.

Development of Comprehension Tests

A twenty-five item multiple-choice test with five alternatives to each item was written for each passage. The following procedure was used in an effort of overcoming the difficulties inherent in using comprehension tests as measures of difficulty.

(1) A comprehension test was written for each passage by a teacher of the grade level for which the passage was intended. Specific directions were given to each teacher about the content and form of the tests (See Directions for Writing Comprehension Tests over Mathematical Passages in Appendix B).

(2) A professional mathematician studied the mathematical content of each passage independent of the comprehension test written by the teacher. He listed the concepts and principles included in each passage and estimated the percent of each passage used to communicate the concept or principle. The first two columns of Table 1 is an example of a listing of concepts, principles and percents for one passage, the passage on Logic. (See Appendix C for the passage).

(3) A trained test-constructor fit the questions written by the teachers into the model provided by the mathematician. When necessary, changes and additions to the model or questions were made only after careful consid-

eration.

(4) Each test was carefully studied for content validity, language, and format by two other trained test-constructors.

(5) The original test-constructor put the tests in final form, using the same format for all twenty-two comprehension tests. The last two columns of Table 1 contain the number of items and percent of items from the comprehension test for Logic in each content category. A comparison of the two columns on percents illustrates how the test-constructors attempted to follow the model provided by the mathematician.

(6) Comprehension tests were administered to small groups of subjects and tests were revised where necessary.

These stages were used as an effort to check the logical validity of each item and the comprehensiveness of passage coverage by the items. No more than three items in each test were transfer items and no item was constructed which fell into cognitive domain taxonomy levels higher than application.

An example of a comprehension test is given in Appendix C. Table 2 gives a listing of items and their categories as established in Table 1 for the passage on Logic.

Construction of Cloze Tests

Two cloze test forms of 100 items each were written for all of the 22 passages. Appendix C gives an example of two cloze forms written over the Logic passage.

Cloze tests were constructed by deleting every fifth word-token or math-token from passages and replacing them with blanks. Ordinary English words like is, go and store; mathematical words like associative, add, and hexagon; and mathematical symbols like =, +, > and 2 were deleted. Any word-token or math-token in the passage on mathematics

Table 1. Model Used to Develop Comprehension Test for Logic Passage.

Content	Percent of Content in Passage as Determined by Mathematician	Number of Items on Comprehension Test	Percent of Items on Comprehension Test (Each item = 4%)
A Compound Sentence Definition and Recognition	5%	1	4%
B Meaning and Symbols for: Conjunction (and; $\wedge$) Disjunction (or; $\vee$) Negation (not; $\sim$)	30%	8	32%
C Truth Value for: Conjunction Disjunction Negation	20%	5	20%
D Meaning and Symbols for: Conditional (if-then; $\rightarrow$) Antecedent, Consequent	15%	4	16%
E Converse, Inverse, Contrapositive. Symbol $\leftrightarrow$	30%	7	28%

Table 2. Items in each Category on Logic Comprehension Test.

	Category	Items
A[a]	Compound Sentences	9
B	Conjunction, Disjunction, Negation	1, 7, 11, 15, 17, 19, 20, 24
C	Truth Values	3, 5, 6, 13, 18
D	Conditional	8, 10, 14, 22
E	Converse, Inverse, Contrapositive	2, 4, 12, 16, 21, 23, 25

[a] see Table 1 for detail.

was able to be sampled in the cloze test. The two forms were obtained by beginning the deletion with different tokens in the two forms. The subject attempted to complete the passage. His score for each passage was the number of responses which matched the deleted material.

Because of the concentrated symbolism of mathematics, blanks of two different lengths replaced tokens. This prevents distortion of the visual representation of the passage. In order to differentiate blanks used for deleted tokens from vincula used in fractions, blanks which replaced tokens were typed in red.

In addition, the _____ of addends does not _____ the sum.

Example:

$$6\ ___\ \frac{1}{4} = \frac{4}{4} + \frac{__}{4} = \frac{2}{4}$$

Figure 2. Sample Deletion in Cloze Tests.

Experimental Procedures

Subjects were enrolled in Grades 7 through 10 in fourteen grade and high schools in Michigan. There were 2445 subjects who completed the study.

A treatment consisted of a response to a cloze test followed a week later by a study of a passage and a response to a comprehension test over the passage. Each subject responded to only one cloze test. The passage studied later was the passage from which the cloze test was constructed. There were forty-four treatment groups, as determined by the two cloze tests over each passage. Subjects were randomly assigned to treatments. For each passage, subjects in the two groups (Group 1, Group 2) received different cloze forms but the same comprehension test. Appendix C gives a sample of materials used by students, with directions to accompany them. Materials for each subject were placed in an envelope to insure the fact that the correct materials would be obtained at the second treatment session.

Meetings were held with teachers to explain the

rationale of the research and the experimental procedures. Teachers administered the research in their classrooms. (See Appendix B for Directions to Teachers, Day 1 and Day 2).

For comprehension tests, students responded on mark-sense cards. However, students answered directly on cloze tests. Responses from cloze tests were later transferred to mark-sense cards as right or wrong answers. All scoring was accomplished on the computer.

The K-R internal consistency formula 20 coefficient was used as the index of reliability for both cloze and comprehension tests. Product-moment and rank-order correlations were obtained to compare the means of results on cloze tests and comprehension tests for individual grades and across grades.

Results

This research was directed toward the development and evaluation of cloze tests as valid measures of difficulty for mathematical English. As an important step in the process, comprehension tests were constructed as criterion measures of difficulty. Before reporting results which compare comprehension tests and cloze tests, reliabilities and rankings of comprehension and cloze tests are presented.

Reliability Coefficients

The K-R internal consistency 20 coefficient was calculated as the measure of reliability for comprehension and cloze tests. The results of these reliabilities are presented below and in Appendix A.

Comprehension Tests

For forty-four comprehension test groups, the coefficients ranged from 0.62 to 0.95 with twenty-six of the coefficients greater than 0.80. Table 5 in Appendix A gives the number of subjects, means, standard deviations, and reliability coefficients for the comprehension tests.

Cloze Tests

For forty-four different cloze tests, two over

each passage, the coefficients ranged from 0.82 to 0.97 with thirty-six of the coefficients greater than 0.90. Table 6 in Appendix A gives the number of subjects, means, standard deviations, and reliability coefficients for the cloze tests.

Ranking by Different Groups

Spearman's rank-order correlation coefficients were obtained using rankings of means of comprehension and cloze test results for groups of subjects who had different cloze forms over the same passage. The correlation between the ranking of means for the comprehension tests was 0.94 and for the cloze tests was 0.82. (see Table 3).

Correlation by Grade

Correlations between the rankings of means on comprehension tests were compared for different grades. Correlations between the means on cloze tests were compared for different grades. All correlations between means on cloze tests for different grades were at least 0.80 (see Table 9, Appendix A). Table 10 in Appendix A reveals that all correlations between the means on comprehension tests for different grades were at least 0.82.

Comparison Between Comprehension and Cloze Tests

Product-moment coefficients were used to compare means of comprehension tests with means of cloze tests for the same passages. Rank-order coefficients compared the rankings of means of comprehension tests with the means of cloze tests. The product-moment correlations between means of comprehension tests and cloze tests were: Group 1, 0.76; Group 2, 0.80; Combined Groups, 0.81. The rank-order correlations between rankings of means of comprehension tests and cloze tests were: Group 1, 0.81; Group 2, 0.80; Combined Groups, 0.83. Correlations between comprehension tests and cloze tests are summarized in Table 3.

The means of the cloze and comprehension tests were compared for each grade. The product-moment correlations between means of comprehension test and cloze test means by grade were: Grade 7, 0.84;

Table 3. Correlations of Means for Cloze and Comprehension Tests.

	Group 2 (Cloze Test 2)	Group 1 Comprehension Test	Combined Groups Comprehension Test
Group 1 (Cloze Test 1)	$\rho^a = 0.82$	$\rho = 0.81$ $r = 0.76$	
Group 2 Comprehension Test	$\rho = 0.80$ $r = 0.80$	$\rho = 0.94$	
Combined Groups Cloze Test			$\rho = 0.83$ $r = 0.81$

[a] ρ = rank-order coefficient
r = product-moment coefficient

Grade 8, 0.81; Grade 9, 0.74; Grade 10, 0.79. The rank-order correlations between rankings of means of comprehension tests and cloze tests by grade were: Grade 7, 0.85; Grade 8, 0.81; Grade 9, 0.74; Grade 10, 0.80. Correlations by grade are summarized in Table 4.

Table 4. Correlation by Grade of Means for Cloze and Comprehension Tests.

Grade	Product-Moment	Rank-Order
7	0.84	0.85
8	0.81	0.81
9	0.74	0.74
10	0.79	0.80

Discussion

Munnally (1967, p.226) reports that reliabilities of 0.60 or 0.50 are satisfactory in the early stages of research on prediction tests. In fact, efforts at increasing reliabilities beyond 0.80 are often wasteful. Since all reliabilities of comprehension tests in this study are greater than 0.60 and more than half are greater than 0.80, all reliabilities of the comprehension tests are high enough to be used.

In the construction of the comprehension tests special attention was given to these factors: proper sampling of content from passages for questions, level at which questions were written, language, and format. All of these were efforts at guaranteeing the content validity of the comprehension tests.

The predictive validity of comprehension tests as measures of comprehension was assumed. Since reliabilities are high enough for basic research and since the tests have content validity, it is concluded that the comprehension tests can be used as criterion measures to test the validity of cloze tests as

measures of difficulty for mathematical English.

Not only were reliabilities of individual comprehension tests high for the forty-four groups used in the study, but the means of twenty-two comprehension tests on different passages were ranked almost the same by the two independent groups of subjects assigned randomly to Group 1 or Group 2 for each passage. Thus, the ranking of comprehension tests is reliable. It can be futher noted from Table 5 that only five of the passages had a difference between the means of more than 1.0 for the two groups.

Reliabilities of all cloze tests were very high. One factor which accounted for the high reliabilities was the length of the tests. It is possible to create longer cloze tests than comprehension tests since (1) items on tests are easily made, (2) many samples for items are available, and (3) items are responded to quickly.

The rank-order correlation of the means between groups using different forms of cloze tests across passages was highly significant. The rank-order correlation was not as high for the cloze tests as for the comprehension tests. This can be explained by the fact that the comprehension tests were exactly the same for the two groups. Only the subjects were different. However, the cloze tests were of different forms for the two groups. So, test forms as well as subjects were different.

There was a direct and consistent relation between performance on cloze and comprehension tests and grade level (see Tables 7 and 8, Appendix A). In general, for each passage, mean scores increased with grade level for both cloze and comprehension tests. This does not necessarily imply that subjects of different grade levels rank the twenty-two passages in the same way. Comparisons were made between grade levels across twenty-two passages. Significant product-moment correlations were found between the means of results for subjects in any two grades on both types of tests (see Tables 9 and 10, Appendix A). A study of the results reveals that as grades are closer together the results exhibit a stronger relationship. This trend may have implications for the development

of precise readability formulas that would take into account the grade level of the student.

Such high reliabilities and correlation rankings of cloze and comprehension tests both within and across grade levels allowed for the study of the validity of the cloze form using the comprehension test as the criterion measure.

A study of the correlation of the means of comprehension and cloze tests across grade levels reveals that a strong relation exists between the two types of tests both when a single form of a cloze test is used for a passage and when the average of the two forms is obtained. A study of Table 3 shows that the correlation coefficients for cloze and comprehension tests are about the same whether one uses the scores of Group 1, Group 2, or the combined groups. Consequently, one form ranks the passages as well as combined forms in relation to comprehension tests.

The rank-order correlation between the means of comprehension tests and cloze tests was found to be 0.83. A study of the comprehension test and cloze test reliabilities for the forty-four groups indicates that 0.79 and 0.95 could be used as rough estimates of the respective tests. Considering these reliabilities, the highest possible correlation which could exist between comprehension and cloze tests is 0.86. It appears that the correlation of 0.83 for comprehension and cloze test means approaches a ceiling for this measure.

The correlations obtained between individual and combined forms of cloze tests with comprehension tests are strong evidence of the relation between the two tests. Since the comprehension tests were constructed as criterion measures of the difficulty of the mathematical passages, the predictive validity of the cloze tests as measures of difficulty is supported. Cloze tests, as constructed, are highly reliable measures. Their content validity has been discussed earlier. All evidence points to the fact that cloze tests can be used as criterion measures of difficulty for mathematical English passages across grade levels.

The preceding paragraphs considered the correlation of comprehension and cloze tests across grade levels. Results from individual grades are consistent with results across grades. For each grade, the correlations of means for cloze and comprehension tests are highly significant. For Grade 9 only, there appears to be a difference between the grade correlation and the correlation across grades. These results indicate that for each grade from seven to ten cloze tests can be used as criterion measures of difficulty for mathematical English passages.

Conclusion

Within the limitations of this study the results seem to justify the following conclusions:

(1) The comprehension tests written for this study are satisfactory criterion measures of reading difficulty for mathematical English.

(2) Cloze tests written over mathematical passages are highly reliable measures.

(3) Correlations of the mean scores between different grade levels (Grades 7 to 10) are highly significant for:
   (a) the ranking of comprehension tests over twenty-two mathematical passages.
   (b) the ranking of cloze tests over twenty-two mathematical passages.

(4) Correlations of the means between cloze and comprehension tests over mathematical passages are significant for:
   (a) combined grades (Grades 7 to 10).
   (b) individual grades.

(5) Finally, adapted cloze tests over mathematical English passages are reliable and valid predictors of reading difficulty for grades 7 to 10.

Recommendations

As a result of this study, cloze scores may be

substituted for traditional reading comprehension test scores as criterion measures in establishing reading difficulty prediction formulas for mathematics. The desirability of this substitution becomes evident when one considers the high reliability of cloze tests, the nearness in syntactical and semantic structure of cloze tests to the actual passages, and the ease of constructing cloze tests in contrast to traditional reading comprehension tests.

The next step in this research could be to work with many more than twenty-two passages to generate an optimum multiple regression function or readability formula that predicts cloze scores (and thus readability) from a set of variables important to the mathematical language. Publishers, teachers, and textbook selection committees could use the formula without having to construct tests of any kind to administer to students.

It seems likely that the technology developed in this series of studies would be applicable in a variety of specialized languages which traditional readability formulas fail to fit. In particular readability assessment in any language which employs a substantial number of non-alphabetic symbols and non-word-tokens seems likely to profit from this line of inquiry. For example, readability assessment in chemical English, physical English, or engineering English seems likely to benefit. The entire spectrum of technical writing employing special vocabulary and non-alphabetic symbol systems could ultimately enjoy efficient readability analyses as the methodology purposed in this study reaches full development.

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Table 5. Comprehension Tests, Two Groups.

Passage	Number of Subjects	Mean	S.D.	KR-20 Coefficients	S.E.
A Precision	52	16.0577	4.5262	0.7954	2.0476
	58	15.4310	5.2985	0.8600	1.9827
B Exponents	57	15.9825	6.2920	0.9011	1.9790
	50	16.9200	5.6887	0.8831	1.9446
C Metric System	55	12.1273	5.4503	0.8447	2.1477
	55	12.1636	5.3256	0.8368	2.1513
D Logic	55	9.8909	5.1448	0.8224	2.1680
	51	9.8431	4.7807	0.7914	2.1836
E Polyhedra	58	11.1207	4.3572	0.7418	2.2141
	55	11.5636	4.3109	0.7294	2.2423
F Polynomials	55	9.8571	5.1608	0.8338	2.1033
	56	9.6140	4.9080	0.8233	2.0759
G Multiplication	56	18.6786	5.1632	0.8813	1.7790
	55	19.3273	4.6708	0.8609	1.7420
H Polygons	57	17.1228	4.4524	0.8024	1.9790
	54	16.8335	4.7929	0.8241	2.0103
I Sequence	55	9.7091	3.5312	0.6215	2.1724
	55	10.7636	4.0550	0.7023	2.2124

Table 5. (continued) Comprehension Tests, Two Groups.

Passage	Number of Subjects	Mean	S.D.	KR-20 Coefficients	S.E.
J Relations	57	11.7895	4.2499	0.7282	2.2156
	55	12.8182	5.6833	0.8561	2.1558
K Whole Numbers	56	15.7857	4.5476	0.8187	1.9364
	55	16.8000	4.3563	0.8117	1.8904
L Statistics	58	12.0000	3.3821	0.6246	2.0723
	55	11.5273	4.2985	0.7750	2.0391
M Matrices	59	12.5424	5.2204	0.8434	2.0529
	56	13.6250	5.7226	0.8801	1.9813
N Triangular Numbers	57	13.2281	4.6599	0.8182	1.9871
	56	13.2857	4.8905	0.8360	1.9808
O Arrangements	57	19.1930	6.7492	0.9472	1.5515
	56	20.8036	5.4753	0.9278	1.4712
P Convex Figures	57	11.4912	4.2009	0.7226	2.2127
	52	10.8846	3.5791	0.6339	2.1478
Q The Parabola	58	12.3621	4.0206	0.7536	1.9956
	54	12.5357	3.4534	0.6612	2.0100
R A Matrix	56	12.6071	4.5753	0.8017	2.0373
	54	12.8000	4.5963	0.7914	2.0994

Table 5. (continued) Comprehension Tests, Two Groups.

Passage	Number of Subjects	Mean	S.D.	KR-20 Coefficients	S.E.
S New Mathematics	59	16.4746	3.9843	0.7426	2.0213
	58	16.8793	3.7607	0.7164	2.0026
T Golden Section	58	12.7931	3.9326	0.7135	2.1049
	53	13.2264	3.8613	0.6980	2.1218
U Geometric	56	17.3214	4.9547	0.8512	1.9114
	58	17.6034	4.6714	0.8259	1.9493
V Graphs	54	14.5370	4.5876	0.8037	2.0327
	52	14.6923	5.3488	0.8550	2.0368

Table 6. Cloze Tests, Two Forms.

Passage	Number of Subjects	Mean	S.D.	KR-20 Coefficient	S.E.
A Precision	52	52.8654	14.0950	0.9261	3.8329
	58	49.8103	15.7752	0.9411	3.8285
B Exponents	57	46.2105	19.7427	0.9609	3.9045
	50	53.3800	23.3176	0.9739	3.7686
C Metric System	55	29.4182	14.4449	0.9388	3.7163
	55	33.0000	13.7450	0.9280	3.6869
D Logic	55	41.6909	14.9689	0.9322	3.8964
	51	30.7843	15.6759	0.9442	3.7033
E Polyhedra	58	24.7241	11.7739	0.9145	3.4423
	55	30.4545	10.5054	0.8843	3.5736
F Polynomials	55	28.3091	13.8383	0.9347	3.5479
	56	32.6964	16.0332	0.9574	3.7213
G Multiplication	56	52.8393	17.6375	0.9535	3.8027
	55	54.6909	16.7020	0.9510	3.6987
H Polygons	57	49.4386	17.3720	0.9472	3.9912
	54	45.2222	16.4577	0.9427	3.9396
I Sequence	55	33.6727	16.1234	0.9492	3.6326
	55	30.2000	14.4343	0.9349	3.6840

Table 6. (continued) Cloze Tests, Two Forms

Passage	Number of Subjects	Mean	S.D.	KR-20 Coefficient	S.E.
J Relations	57	26.1228	13.5173	0.9276	3.6371
	55	34.4182	16.6485	0.9490	3.7600
K Whole Numbers	56	48.2857	13.1836	0.9195	3.7403
	55	57.6909	12.7437	0.9117	3.7868
L Statistics	53	39.7241	14.4693	0.9321	3.7707
	55	31.3636	15.2101	0.9403	3.7177
M Matrices	59	53.2203	16.7765	0.9470	3.8605
	56	57.3571	17.7594	0.9547	3.7813
N Triangular Numbers	57	45.1053	11.5398	0.8958	3.7254
	56	45.5179	13.8577	0.9260	3.7689
O Arrangements	57	55.4561	12.7952	0.9118	3.8000
	56	51.6786	12.1193	0.9039	3.7573
P Convex Figures	57	29.1579	10.5455	0.8920	3.4655
	52	25.6731	9.0114	0.8652	3.3090
Q The Parabola	58	34.1034	12.2628	0.9127	3.6231
	54	44.7963	8.7726	0.8243	3.6774
R A Matrix	56	47.4643	15.1921	0.9270	4.1044
	54	39.9630	13.8686	0.9234	3.8372

Table 6. (continued) Cloze Tests, Two Forms.

Passage	Number of Subjects	Mean	S.D.	KR-20 Coefficient	S.E.
S New Mathematics	59	42.0847	10.8267	0.8935	3.5327
	58	43.7241	10.3683	0.8798	3.5951
T Golden Section	58	37.6897	15.9442	0.9463	3.6939
	53	36.0189	8.9216	0.8167	3.8200
U Geometric Figures	56	54.2143	14.6172	0.9259	3.9777
	58	51.7931	17.3759	0.9501	3.8818
V Graphs	54	49.7222	16.5728	0.9399	4.0619
	52	49.9423	19.5933	0.9601	3.9135

Table 7. Comprehension Tests: Means and Number of Subjects by Grade.

Passage	7		8		9		10	
A Precision	14.04	28	15.08	26	16.33	27	17.38	29
B Exponents	11.39	28	17.33	27	17.96	27	19.40	25
C Metric System	9.93	30	12.33	27	11.92	26	14.63	27
D Logic	6.79	28	9.00	29	10.80	25	13.54	24
E Polyhedra	9.20	30	10.54	28	12.32	28	13.52	27
F Polynomials	6.21	29	8.00	26	10.79	28	13.39	28
G Multiplication	15.69	29	19.92	25	19.27	30	21.41	27
H Polygons	15.33	30	17.08	26	17.88	26	17.79	29
I Sequence	7.67	27	10.43	28	9.76	29	13.12	26
J Relations	9.10	30	12.21	28	12.27	26	15.82	28
K Whole Numbers	14.53	30	17.00	29	16.20	25	17.56	27
L Statistics	10.36	28	10.97	30	12.48	27	13.36	28
M Matrices	10.41	29	13.31	29	12.52	27	15.90	30
N Triangular Numbers	12.21	28	12.17	30	14.22	27	14.54	28

Table 7. (continued) Comprehension Tests: Means and Number of Subjects by Grade.

Passage	7		8		9		10	
O Arrangements	18.50	28	20.07	29	21.24	29	20.11	27
P Convex Figures	9.46	24	10.86	29	11.04	27	13.14	29
Q The Parabola	11.62	25	11.07	29	12.57	27	14.39	31
R A Matrix	10.38	28	12.36	28	13.58	26	14.64	28
S New Mathematics	14.65	26	17.70	30	16.21	28	17.73	33
T Golden Section	11.35	26	12.90	29	12.62	29	15.11	27
U Geometric Figures	15.31	26	17.87	30	17.67	27	18.71	31
V Graphs	11.27	26	13.59	29	15.58	24	18.07	27

Table 8. Cloze Tests: Means and Number of Subjects by Grade.

Passage	7		8		9		10	
A Precision	47.64	28	48.27	26	53.93	27	54.93	29
B Exponents	34.82	28	46.70	27	52.67	27	65.80	25
C Metric System	24.43	30	30.04	27	32.65	26	38.51	27
D Logic	26.14	28	33.45	29	41.04	25	47.29	24
E Polyhedra	22.10	30	26.62	28	30.51	28	31.48	27
F Polynomials	22.34	29	23.67	26	35.11	28	40.89	28
G Multiplication	46.83	29	54.24	25	53.17	30	61.41	27
H Polygons	42.83	30	48.00	26	51.62	26	47.76	29
I Sequence	23.15	27	33.25	28	34.83	29	36.42	26
J Relations	24.60	30	32.14	28	27.04	26	37.18	28
K Whole Numbers	48.60	30	52.83	29	54.28	25	56.11	27
L Statistics	32.75	28	34.00	30	36.74	27	39.17	28
M Matrices	49.10	29	56.00	29	56.37	27	59.40	30
N Triangular Numbers	41.75	28	45.07	30	45.44	27	49.00	28

Table 8. (continued) Cloze Tests: Means and Number of Subjects by Grade.

Passages	7		8		9		10	
O Arrangements	50.18	28	55.03	29	52.90	29	56.30	27
P Convex Figures	22.71	24	27.62	29	27.52	27	31.31	29
Q The Parabola	35.60	25	35.93	29	41.41	27	43.45	31
R A Matrix	34.93	28	42.00	28	47.69	26	51.11	28
S New Mathematics	38.50	26	45.13	30	40.71	28	46.18	33
T Golden Section	30.08	26	37.45	29	37.03	29	42.70	27
U Geometric Figures	49.65	26	55.43	30	52.74	27	53.61	31
V Graphs	38.04	26	55.59	29	51.38	24	54.85	27

Table 9. Cloze Tests: Product-Moment Correlations by Grade, Over 22 Passages.

	7	8	9
8	0.93		
9	0.90	0.92	
10	0.80	0.87	0.93

Table 10. Comprehension Tests: Product-Moment Correlations by Grade.

	7	8	9
8	0.92		
9	0.91	0.94	
10	0.82	0.94	0.94

APPENDIX B

DIRECTIONS TO TEACHERS
DAY I

Passing out papers

a) Pass one envelope to each student. Take envelopes from the FRONT of the row of envelopes.

b) Check to see that each student has a pencil.

Giving Directions

a) Tell students:"There are three packs of papers in your envelope. Take out the pack with the pink sheet."

b) Tell students:"The number on the pink paper is not important to you. It is used only to keep the material in order."

c) Read directions aloud while students read them silently. Pause for students to complete directions.

d) Tell students:"If a word doesn't fit in a blank, write it above or to the side."

e) Tell students "You will have the entire period to complete the test. An answer for each blank should be given."

f) If students ask questions, re-read appropriate parts of the directions. Do not give more information than is contained in the directions.

g) If a student asks if this will count for his grade, tell him no. "This is a test we are using to find out more about the reading of mathematics."

During the Test

a) Collect the envelopes. Make sure that names are on the envelopes. These will be passed out again at the beginning of the second

testing session.

b) If a student has difficulty, assist him.

Collecting of Tests

a) If a student does not have time to finish the test, have him mark TIME under the number in the upper right-hand corner.

b) Collect all tests. Keep all tests together. Do not put them back in the envelopes. Keep the tests. They will be collected after the second testing session.

Estimated Time

45 minutes.

DIRECTIONS TO TEACHERS
DAY 2

Distribute Envelopes

Giving Directions for the Yellow Set

a) Tell students: "Take the yellow set of papers out of the envelope."

b) Read directions aloud while students read them silently.

c) Tell students: "You will have 12 minutes to read and study the pages. A test will follow. Begin."

d) Record the beginning time.

After 12 minutes

a) Tell students: "Stop reading. Place the yellow sheet in the envelope. Take the white set and the cream card out of the envelope."

b) Read directions aloud while students read them silently. Pause for students to write names on cards.

c) Tell students: "You have the rest of the period to complete the test. Begin."

During the Test

a) Check to see that students are filling in the cards correctly.

b) Inform students when there are 5 minutes left.

Collecting of Tests

a) If a student does not finish the test, have him mark TIME on the card above his name.

b) Collect cream cards.

c) Collect envelopes.

d) Collect pencils.

Materials to be returned to the Mathematical Reading Study Center:

1) Pink tests
2) Cream cards
3) Pencils

Other materials can be discarded.

DIRECTIONS FOR WRITING COMPREHENSION TESTS OVER MATHEMATICAL PASSAGES

1) All mathematical content in the passage is to be tested.

2) The number of items on a particular topic should be approximately proportional to the amount of emphasis placed on that topic in the passage.

3) Approximately 25 items should be written over each passage.

4) Items should be multiple-choice with five responses to each item.

5) Distractors for one item should not give clues for the answer to another item.

6) Let your language conform to the language of the passage. If you need to introduce new words, especially as alternative responses, simpler language is better than complicated language. Symbols should conform, when possible, to the symbols of the passage.

7) Items should test:

   a) Recall or recognition of facts, concepts, principles, methods, trends, et cetra contained in the passage.

   or

   b) Comprehension of these facts, concepts, principles, methods, trends, et cetra.

   Some ways in which comprehension can be tested are:
   1) restating using different words,
   2) applying a given principle,
   3) using different numerical examples,
   4) varying the technique slightly.

8) Items should not test levels of abstraction higher than recall, recognition, and comprehension. Such higher levels include application (without principle given), analysis, synthesis, and evaluation.

Here are examples of multiple choice test items:

1. Which of the following contains a common fraction:
   a. 10 b. 3% c. ½ d. .01 e. 2 x 5

2. Which tells how fast you run?
   a. your age
   b. your size
   c. your capacity
   d. your speed
   e. your altitude

3. If you said each set of numerals below out loud, which would be counting?
   a. 2-7-3-1
   b. 2-0-5-0
   c. 8-5-1-0
   d. 1-2-3-4
   e. 10-15-16-18

4. A gallon equals:
   a. 4 quarts
   b. 2 pints
   c. ½ quart
   d. 4 pecks
   e. 12 units

5. This symbol > means:
   a. is equal to
   b. is greater than
   c. is the square of
   d. is the square root of
   e. is less than

6. The commutative law for addition says:
   a. $a + 0 = a$
   b. $(a + b) + c = a + (b + c)$
   c. $a + b = b + a$
   d. $a + (-a) = 0$
   e. $a + a = 2a$

APPENDIX C

SAMPLES OF TESTING INSTRUMENTS[1]

DIRECTIONS TO STUDENTS FOR CLOZE TESTS

Name_____ Grade____ School_____

Print your name, grade, and school in the blanks above. Print your name on the front of the outside envelope. Put the envelope in the UPPER LEFT HAND CORNER of your desk.

This reading test was made by putting a blank in the place of every fifth word or symbol of a passage from a mathematics book. Look for the red! Guess the word or symbol which has been left out, and write it in the red blank. Don't fill in anything except the red blanks.

This is an example:

$$a + ___ = b + a.$$

You can write b in the blank like this:

$$a + \underline{\ b\ } = b + a.$$

Try to put the word or symbol which you think the author had there.

Put one and only one word or symbol in each red blank. The word or symbol could be a number like __6__ or a letter like __G__. It could be a symbol like __x__, or __+__, or __)__, or __=__. It could be a contraction __can't__ or part of a hyphenated word like __color__-bearer. It could be an abbreviation like __Mr.__. It could be an ordinary word like multiplication, or __Jones__.

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[1]Due to the number of passages and tests used in this study only one sample of each instrument is included in the report. Information concerning additional materials can be obtained from the Project Director.

The blanks are two sizes, _____ and ___. The size of the blank does not necessarily tell you the length of the word or symbol. An English word could go in a short blank, and a symbol could go in a long blank.

Try to fill in every blank. You probably do not know the mathematics which is on these pages. Some blanks are easier than others. When you finish the test, go back and fill in the harder blanks. Guess, if necessary. Continue to work until you have filled in all the blanks.

Example:

The following equation is _____:

142 = ___00 + 4___ + 2.

The answer could be:

The following equation is ___true___:

142 = __100 + 40__ + 2.

A CLOZE TEST: ONE FORM

LOGIC--COMPOUND SENTENCES[1]

_____ compound sentence consists of _____ simple sentences joined by _____ connective. If the connective _____ "and" represented by the _____ "$\wedge$," the compound sentence _____ called a conjunction. The _____ sentence $8 < n$ _____ $n < 12$ _____ a conjunction. It could _____ written as $8 <$ _____ $\wedge n < 1$___ or as $8 <$ _____ < 12. Usually _____ logic the letter p _____ the first simple sentence _____ the letter q the _____ simple sentence so that _____ $\wedge q$ represents a _____.

If the connective is "_____" represented by the symbol "_____," the compound sentence is _____ a disjunction. The number _____ $n > 8$ or _____ $= 8$ is a _____. It could be written _____ $n > 8 \vee$ _____ $= 8$ or as _____ ≥ 8. In _____ $p \vee q$ symbolizes

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_____ disjunction.

A conjunction is _____ if and only if _____ simple sentences are true. _____ either sentence is false _____ both sentences are false, _____ conjunction is false.

A _____ is true if either _____ of the simple sentences _____ true or both sentences _____ true. If both sentences _____ false, the disjunction is _____. See the summary in _____ truth table at the _____.

p	q	p ∧ ___	p ∨ q
T	___	T	T
T	F	___	T
F	T	F	___
F	F	F	F

_____ negation of a sentence _____ the opposite of the _____. The negation of b _____ 4 is b ≠ _____; the negation of x _____ 10 is x _____ 10. If the _____ is true, the negation _____ false; if the sentence _____ false, the negation is _____. Negation is indicated by _____ prefix symbol "~." If _____ is the sentence, then _____

p (read "not p") _____ the negation.

The negation _____ a negation is the _____ sentence

$\sim(\sim__) = p$

p	___p
T	F
F	___

An implication is a _____ sentence (sometimes called a _____) consisting of an antecedent (_____ following "if") and a _____ (sentence following "then"). The _____: "If a triangle has _____ equal sides, then it _____ 3 equal angles, "and" _____ 4x = 2 _____, then x = 6.," _____ "if line m is _____ to line n, then _____ n is perpendicular to _____ m," are implications. The _____ is sometimes called the _____ and the consequent called _____ conclusion. Using p as _____ antecedent, q for the _____, and an arrow between _____, we express an implication _____ $p \longrightarrow q$ which _____ "if p, then q" _____ "p implies q."

If _____ interchange the antecedent and _____ of a conditional sentence, _____ implication results which is _____ converse of the first. _____ converse of $p \longrightarrow$ _____

is $q \longrightarrow p$. _____ expression $p \longleftrightarrow q$ _____ that an implication and _____ converse are equivalent since _____ implies the other.

If _____ negate both the antecedent and consequent of an implication, the resulting implication is the <u>inverse</u> of the first. The inverse of $p \longrightarrow q$ is $\sim p \longrightarrow \sim q$ which is read "not p implies not q."

If we negate both the antecedent and consequent of an implication and then interchange them, the resulting implication is the <u>contrapositive</u> of the first. The contrapositive of $p \longrightarrow q$ is $\sim q \longrightarrow \sim p$ which is read "not q implies not p."

A CLOZE TEST: ANOTHER FORM

LOGIC--COMPOUND SENTENCES[1]

A _____ sentence consists of two _____ sentences joined by a _____. If the connective is "_____," represented by the symbol "_____," the compound sentence is _____ a conjunction. The number _____ $8 < n$ and _____ < 12 is _____ conjunction. It could be _____ as $8 < n$ _____ $n < 12$ _____ as $8 < n$ _____ 12. Usually in _____ the letter p represents _____ first simple sentence and _____ letter q the second _____ sentence so that p _____ q represents a conjunction.

_____ the connective is "or", _____ by the symbol "$\vee$," _____ compound sentence is called _____ disjunction. The number sentence _____ > 8 or n _____ 8 is a disjunction. _____ could be written as _____ $> 8 \vee$ n _____ 8 or as $n \geq 8$. In logic _____ $\vee$ q

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symbolizes a _____.

A conjunction is true _____ and only if both _____ sentences are true.

If _____ sentence is false or _____ sentences are false, the _____ is false.

A disjunction _____ true if either one _____ the simple sentences is _____ or both sentences are _____.

If both sentences are _____, the disjunction is false. _____ the summary in the _____ table at the right.

___	q	p ∧ q	___ ∨ q
T	T	___	T
T	F	F	___
F	T	F	T
___	F	F	F

The _____ of a sentence is _____ opposite of the sentence. _____ negation of b = _____ is b ≠ 4; _____ negation of x ≯ _____ 0 is x > _____ 0. If the sentence _____ true, the negation is _____; if the sentence is _____, the negation is true. _____ is indicated by the _____ symbol

"$\sim$," If p _____ the sentence, then $\sim$_____ (read "not p") is _____ negation:

The negation of _____ negation is the original _____.

$\sim(\sim p$ ___ $= p$

p	$\sim$ ___
T	F
F	T

_____ implication is a conditional _____ (sometimes called a conditional) _____ of an antecedent (sentence _____ "if") and a consequent (_____ following "then"). The sentence: "_____ a triangle has 3 _____ sides, then it has _____ equal angles," and "If _____ $x = 24$, _____ $x = 6$, "and" _____ line m is perpendicular _____ line n, then line _____ is perpendicular to line _____," are implications. The antecedent _____ sometimes called the hypothesis _____ the consequent called the _____. Using p as the _____, q for the consequent, _____ an arrow between them, _____ express an implication as _____ $\longrightarrow q$ which means "_____ p, then q" or "_____ implies q."

If we _____ the antecedent and consequent _____ a conditional sentence, another _____

results which is the _____ of the first. The _____ of $p \longrightarrow q$ _____ $q \longrightarrow p$. The _____ $p \longleftrightarrow q$ symbolizes _____ an implication and its _____ are equivalent since each _____ the other.

If we _____ both the antecedent and the consequent of an implication, the resulting implication is the <u>inverse</u> of the first. The inverse of $p \longrightarrow q$ is $\sim p \longrightarrow \sim q$ which is read "not p implies not q."

If we negate both the antecedent and consequent of an implication and then interchange them, the resulting implication is the <u>contrapositive</u> of the first. The contrapositive of $p \longrightarrow q$ is $\sim q \longrightarrow \sim p$ which is read "not q implies not p."

DIRECTIONS TO STUDENTS
FOR READING

Here are a few pages from a mathematics book. Perhaps you have not studied this mathematics in school. Read the pages and study them carefully. you will have 15 minutes to work. You may write on the papers. All papers are to be put back in the envelope when you are finished. During the second half of this period, you will take a test on the mathematics. The test will ask you to remember what you read, and to use what you read to answer other questions.

When you understand the mathematics, put the papers in the envelope. You may begin to study the passage.

LOGIC--COMPOUND SENTENCES[1]

A compound sentence consists of two simple sentences joined by a connective. If the connective is "and," represented by the symbol " $\wedge$," the compound sentence is called a conjunction. The number sentence $8 < n$ and $n < 12$ is a conjunction. It could be written as $8 < n \wedge n < 12$ or as $8 < n < 12$. Usually in logic the letter p represents the first simple sentence and the letter q the second simple sentence so that $p \wedge q$ represents a conjunction.

If the connective is "or," represented by the symbol " $\vee$," the compound sentence is called a disjunction. The number sentence $n > 8$ or $n = 8$ is a disjunction. It could be written as $n > 8 \vee n = 8$ or as $n \geq 8$. In logic $p \vee q$ symbolizes a disjunction.

A conjunction is true if and only if both simple sentences are true. If either sentence is false or both sentences are false, the conjunction is false.

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A disjunction is true if either one of the simple sentences is true or both sentences are ture. If both sentences are flase, the disjunction is false. See the summary in the truth table at the right.

p	q	$p \wedge q$	$p \vee q$
T	T	T	T
T	F	F	T
F	T	F	T
F	F	F	F

The negation of a sentence is the opposite of the sentence. The negation of $b = 4$ is $b \neq 4$; the negation of $x \not> 10$ is $x > 10$. If the sentence is true, the negation is false; if the sentence is false, the negation is true. Negation is indicated by the prefix symbol "$\sim$." If p is the sentence, then $\sim p$ (read "not p") is the negation.

The negation of a negation is the original sentence.

$$\sim(\sim p) = p$$

p	$\sim p$
T	F
F	T

An implication is a conditional sentence (sometimes called a conditional) consisting of an

antecedent (sentence following "if") and a consequent (sentence following "then"). The sentence: "If a triangle has 3 equal sides, then it has 3 equal angles.," and "If $4x = 24$, then $x = 6$.," and "if line m is perpendicular to line n, then line n is perpendicular to line m." are implications. The antecedent is sometimes called the hypothesis and the consequent called the conclusion. Using p as the antecedent, q for the consequent, and an arrow between them, we express an implication as $p \longrightarrow q$ which means "if p, then q" or "p implies q".

If we interchange the antecedent and consequent of a conditional sentence, another implication results which is the converse of the first. The converse of $p \longrightarrow q$ is $q \longrightarrow p$. The expression $p \longleftrightarrow q$ symbolizes that an implication and its converse are equivalent since each implies the other.

If we negate both the antecedent and consequent of an implication, the resulting implication is the inverse of the first. The inverse of $p \longrightarrow q$ is $\sim p \longrightarrow \sim q$ which is read "not p implies not q."

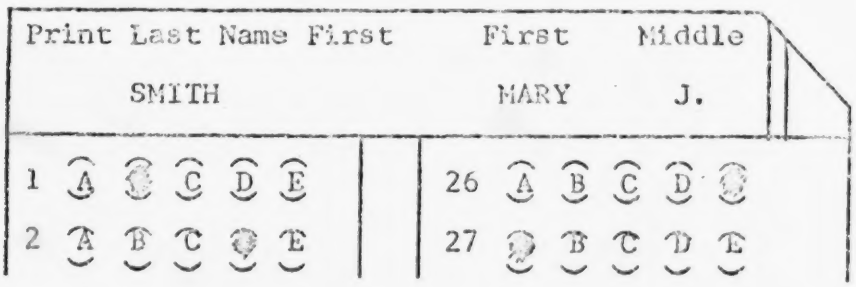
If we negate both the antecedent and consequent of an implication and then interchange them, the resulting implication is the contrapositive of the

first. The contrapositive of $p \longrightarrow q$ is $\sim q \longrightarrow \sim p$ which is read "not q implies not p."

DIRECTIONS TO STUDENTS
FOR COMPREHENSION TESTS

This is a test to see how well you learned what was in the passage you read. Do your best.

The test is multiple choice. All answers are to be placed on the separate answer card. It looks like this:



Print your name on the card NOW!

Use the pencil provided to mark answers. Mark answers as in this example. Fill in the entire space between the marks ◯. The answers chosen above are

1B, 2D, 26E, 27A.

The answer card has positions for 100 answers. Your test has only 25 items. Use only from 1 to 25 in answering the questions. You may write on the test, but be sure you write the answers on the card.

When you finish the test, put the test and card in the envelope. Seal the envelope.

Thank you.

A COMPREHENSION TEST

LOGIC – COMPOUND SENTENCES

Choose one and only one answer to each question.
Choose the best and most complete answer.

1. The connective of a disjunction is:

   a) $\longrightarrow$
   b) $\vee$
   c) $\longleftrightarrow$
   d) $\sim$
   e) $\wedge$

2. The expression $p \longleftrightarrow q$ means that _____ are equivalent.

   a) a contrapositive and implication
   b) a contrapositive and converse
   c) an implication and converse
   d) an inverse and contrapositive
   e) a converse and inverse

3. Let a be a simple sentence. If $(\sim a)$ is false, then a is:

   a) true
   b) false
   c) this depends on a
   d) this depends on $\sim$
   e) this question cannot be answered

4. The converse of $p \longrightarrow q$ is:

   a) $\sim p \longrightarrow \sim q$
   b) $\sim q \longrightarrow \sim p$
   c) $q \longrightarrow p$
   d) $q \longleftrightarrow p$
   e) $\sim p \longleftrightarrow \sim q$

5. If a compound sentence is composed of two simple sentences p and q, such that one is true and the other is false, then _____.

a) $p \vee q$ is always true
b) $p \vee q$ is true only if p is the true sentence
c) $p \vee q$ is true only if q is the true sentence
d) $p \vee q$ is always false
e) $p \vee q$ is neither true nor false

6. If $a \wedge b$ is true then:

a) a or b is true
b) a and b are true
c) a is true but b does not need to be true
d) b is true but a does not need to be true
e) you cannot reach any conclusion

7. $6 > 5$ and $4 < 7$ is a:

a) disjunction
b) implication
c) negation
d) conjunction
e) none of these

8. Given the implication: "If an angle is a right angle, then its measure is 90", the underlined clause is called _____.

a) the conclusion or consequent
b) the negation
c) the inverse of the first clause
d) the antecedent
e) the hypothesis

9. Two simple sentences joined by a connective is called:

a) a contrapositive
b) a conditional sentence
c) a compound sentence
d) a complex sentence
e) an implication

10. In $p \longrightarrow q$, p is called the :

a) statement
b) symbol
c) letter
d) consequent
e) hypothesis

11. A disjunction is represented by:

a) p and q
b) p implies q, and q implies p
c) not p
d) p or q
e) p implies q

12. "If $4x = 0$, then $x = 0$" is the contrapositive of:

a) if $4x \neq 0$, then $x = 0$
b) if $x = 0$, then $4x = 0$
c) if $x \neq 0$, then $4x \neq 0$
d) if $4x \neq 0$, then $x \neq 0$
e) if $x \neq 0$, then $4x = 0$

13. $p = \sim(\sim p)$ is _____.

a) always true
b) true if p is true
c) true if p is false
d) never true
e) this question cannot be answered

14. Consequent and antecedent are terms used to represent the parts of a:

a) negation
b) disjunction
c) conjunction
d) conditional
e) none of these

15. $b = 4$ is called the _____ of $b \neq 4$:

a) inverse
b) negation
c) converse
d) contrapositive
e) none of these

16. Consider the statement: $4x = 8 \longleftrightarrow x = 2$. $4x = 8 \longrightarrow x = 2$ is the _____ of $x = 2 \longrightarrow 4x = 8$.

a) inverse
b) negation
c) contrapositive
d) converse
e) implication

17. The statement $3 < x < 7$ could be written _____.

a) $3 > x > 7$
b) $3 < x \wedge x < 7$
c) $3 < x \vee x < 7$
d) $3 < x \wedge x > 7$
e) $3 > x \vee x > 7$

18. If a compound sentence is composed of two simple sentences p and q, such that one is true and the other is false then _____.

a) $p \wedge q$ is always true
b) $p \wedge q$ is true only if the true sentence is p
c) $p \wedge q$ is true only if the true sentence is q
d) $p \wedge q$ is always false
e) $p \wedge q$ is neither true nor false

19. The statement $\sim(n < 7)$ is equivalent to:

a) $n = 7$
b) $n \neq 7$
c) $n > 7$
d) $n \not> 7$
e) $n \not< 7$

20. The compound sentence $5 \leq x$ could be written _____.

a) $5 = x < 5$
b) $5 < x \vee 5 = x$
c) $5 < x$
d) $5 < x \wedge 5 = x$
e) $5 = x$

21. The inverse of $\sim p \longrightarrow q$ is:

a) $q \longrightarrow p$
b) $q \longrightarrow \sim p$
c) $\sim p \longleftrightarrow q$
d) $p \longrightarrow q$
e) $p \longrightarrow \sim q$

22. Given: "If $4x = 24$, then $x = 6$." This statement is _____.

a) a disjunction where $x = 6$ is a simple sentence
b) a conditional statement where $x = 6$ is the consequent
c) a conjunction where $4x = 24$ is a simple sentence
d) a conditional statement where $x = 6$ is the antecedent
e) an implication where $x = 6$ is the hypothesis

23. The contrapositive of <u>If r then $\sim(s + t)$</u> is:

a) if $\sim r$ then $(s + t)$
b) if r then $(s + t)$
c) if $(s + t)$ then $\sim r$
d) if $(s + t)$ then r
e) none of these

24. If a and b are simple sentences, a conjunction is represented by:

a) $a \wedge b$
b) $a \vee b$
c) a or b
d) $a \longleftrightarrow b$
e) none of these

25. "If $4x \neq 24$, then $x \neq 6$" is the _____ of "If $4x = 24$, then $x = 6$."

a) antecedent
b) converse
c) contrapositive
d) conclusion
e) inverse